

PROBLEMS OF BIOTELEMETRY DURING PROLONGED SPACE FLIGHTS

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## PROBLEMS OF BIOTELEMETRY DURING PROLONGED SPACE FLIGHTS

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## ABSTRACT

The authors discuss some of the problems encountered in the use of telemetry and other information-measuring devices on future spaceships. Results are presented from investigations conducted for the purpose of perfecting means for the improvement of space flight safety. A discussion is given on the selection of physiological, hygienic, and psychomotor parameters needed to carry out scientific research and other tasks on spacecraft. /1 \*

The problems of biotelemetry during prolonged and distant space flights cannot be considered apart from the overall problems being encountered in space flight at its present stage of development.

All completed and planned flights have had and continue to have, to a certain extent, an experimental nature. The launchings of the "Voskhod", "Mercury," and "Gemini" can be considered series launchings only in a certain manner of speaking. In actual fact each experiment had its own distinguishing characteristics and was undertaken to find the answers to definite questions which, for the most part, were being answered for the first time. Therefore, the so-called series spaceships differed fundamentally from one another primarily with respect to the research equipment they carried. There was never a single launch which was intended to repeat a preceding flight exactly.

Flights in space near the earth have gradually changed their purpose. After prolonged existence by man in space had been proven possible, investigation began into his creative activity during flight. Inasmuch as the conditions under which activity was carried out differed greatly in single-seat and multi-seat spaceships during prolonged and brief flights and also during the launch into space, evaluations of the reactions of cosmonauts to the effects of different flight factors were based on a large volume of information.

All previously completed flights were carefully prepared and were terminated according to plan. During these flights the reserve and auxiliary safety systems were used only partially. In the future flights will be more frequent and more complex. Therefore, due to purely objective /2

\*Numbers given in the margin indicate the pagination in the original foreign text.

reasons the number of unplanned situations during flight will undoubtedly grow. In order to prevent dramatic developments during experiments in space, the way in which medico-biological measuring systems on a spaceship are used must be improved.

In this article, along with a discussion of certain problems encountered in the use of telemetry and other information-measuring devices on future spaceships, there will be presented the results obtained from investigations which were conducted for the purpose of perfecting the means for the improvement of flight safety.

The selection of physiological, hygienic, and psychomotor parameters needed to carry out scientific research and applied tasks is one of the more difficult problems. Two contradicting factors are found to be predominant in efforts to solve this problem. One is the need for a large amount of medical information and the other is the limited capability of on-board radiotelemetric systems (ORS). In all previously performed experiments compromise solutions were adopted for the purpose of carrying out the task of performing an operational medical check of the condition of cosmonauts was carried out on the basis of a dynamic analysis of a relatively small number of previously selected parameters. A more precise evaluation of condition and capacity to work was made on the basis of results obtained from a periodic programmed check of the cosmonauts (table).

TABLE

Name of Parameter	Frequency of ORS Query	Radiotelemetric Operating Mode	Information Analysis
1	2	3	4
1. Operational Medical Check.			
Pulse rate	Low	Continuous	Dynamic
Respiration rate	Low	Continuous	Dynamic
Motor activity	Low	Continuous	Dynamic
Body Temperature	Low	Continuous	Dynamic
Pressure in cabin or space suit	Low	Continuous	Dynamic
2. Periodic medical examination			
Electrical cardiac activity	High	Periodic	During transmissions
Respiration actogram	High	Periodic	During transmissions
Seismocardiogram	High	Periodic	During transmissions
Electrical ocular activity	High	Periodic	During transmissions <sup>/3</sup>
Cabin temperature	Low	Periodic	During transmissions
Humidity	Low	Periodic	During transmissions

O <sub>2</sub> Content	Low	Periodic	During transmissions
CO <sub>2</sub> Content	Low	Periodic	During transmissions

### 3. Examination of capacity to work

Coordination of movements	High	Periodic	During transmissions
Muscular effort	Low	Periodic	During transmissions
Time of test	Low	Periodic	During transmissions
Intensity of test	Low	Periodic	During transmissions
Respiration actogram	High	Periodic	During transmissions
Electrical cardiac activity	High	Periodic	During transmissions
Electrical ocular activity	High	Periodic	During transmissions
Electrical cerebral activity	High	Periodic	During transmissions
Cutaneo-galvanic reactions	High	Periodic	During transmissions

### 4. Psychophysiological examinations

Time of stimulus	Low	Periodic	During transmissions
Intensity of stimulus	High	Periodic	During transmissions
Speed of execution	High	Periodic	During transmissions
Precision of execution	High	Periodic	During transmissions
Tendency of reactions	High	Periodic	During transmissions
Electrical cardiac activity	High	Periodic	During transmissions
Electrical cerebral activity	High	Periodic	During transmissions
Electrical ocular activity	High	Periodic	During transmissions
Cutaneo-galvanic reactions	High	Periodic	During transmissions

### 5. Circulation examination

Pressure in cuff	Low	Periodic	During transmissions
Arterial oscillations	High	Periodic	During transmissions

Korotkow sounds	High	Periodic	During transmissions
Electroplethysmogram	High	Periodic	During transmissions
Electrical cardiac activity	High	Periodic	During <u>/4</u> transmissions
Respiration actography	High	Periodic	During transmissions
Seismocardiography	High	Periodic	During transmissions

#### 6. Respiratory function examination

Respiration actography	Low	Periodic	During transmissions
Respiratory volume	Low	Periodic	During transmissions
Respiratory volume rate	Low	Periodic	During transmissions
Time of test	Low	Periodic	During transmissions
Intensity of test	High	Periodic	During transmissions
Electrical cardiac activity	Low	Periodic	During transmissions
O <sub>2</sub> content	Low	Periodic	During transmissions
CO <sub>2</sub> content	Low	Periodic	During transmissions
Moisture	Low	Periodic	During transmissions
Pressure	Low	Periodic	During transmissions
Temperature	Low	Periodic	During transmissions

#### 7. Vestibular reaction examinations

Time of stimulus	Low	Periodic	During transmissions
Intensity of stimulus	High	Periodic	During transmissions
Cutaceo-galvanic reactions	High	Periodic	During transmissions
Electrical cardiac activity	High	Periodic	During transmissions
Electrical ocular activity	High	Periodic	During transmissions
Electrical cerebral activity	High	Periodic	During transmissions

The large number of parameters being measured and the variety in the programs of investigation require the development of appropriate methods and engineering solutions. The problem of selecting the principles underlying the design of a physiological measuring system must be solved in the light of the medical purpose involved and in the light of the general structure and specific nature of the spaceship itself. Such questions as the location, power supply, and connection of medical apparatus are being resolved in the light of the specific conditions which obtain. We consider it advisable to use the apparatus for the operational medical control (OMC) and those for /5 the periodic medical examination (PME) apart from one another. It appears advisable from the point of view of economy of electrical energy and reliability of communication and also greater freedom and convenience in movement by a cosmonaut to provide in the OMC system radiotelemetric communication with the on-board apparatus (Fig. 1) as well as wire communication (Fig. 2).

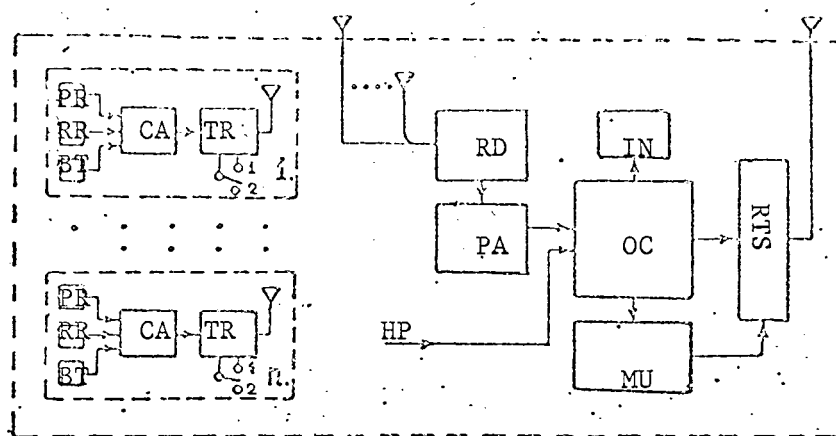


Fig. 1. Functional diagram of circuit for operational medical control: PR - pulse rate; RR - respiration rate; BT - Body temperature; CA - converter-amplifier; TR - transmitter; RD - receiving device; PA - power amplifier; HP - hygiene parameters; IN - indicator; OC - on-board computer; MU - memory unit; RTS - on-board-on-board part of radio-telemetric system.

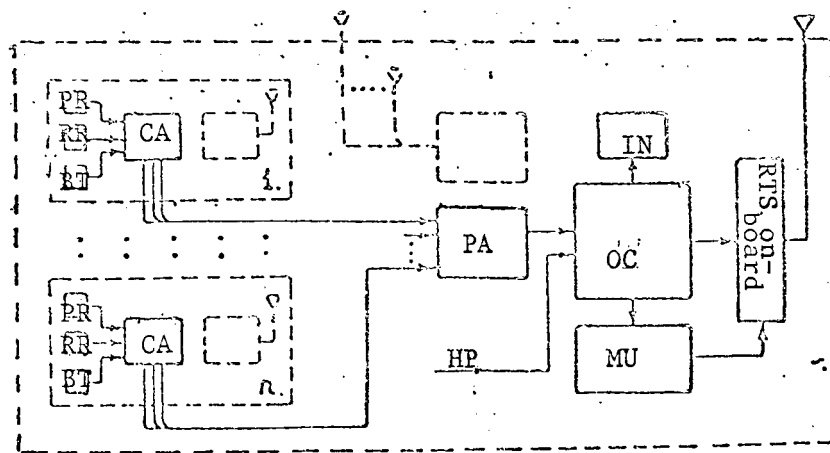


Fig. 2. Functional diagram of system for operational medical control using wire communication between the apparatus on the cosmonaut and the on-board apparatus.

The apparatus for the operational medical control has a more improved <sup>/6</sup> design and with respect to the circuit has been sufficiently well standardized. It has been successful in all space flights on the "Vostok" and "Voskhod." Information from the operational medical control is transmitted in multiplexed form using the transmitter of the radiotelemetric system which operates continuously on short wave. During the ultrashort-wave transmissions operational medical control information was transmitted directly to receiver points.

The periodic medical examination apparatus (Fig. 3) is more complex and is in essence a purely experimental device intended for carrying out a primarily scientific research program for each particular flight. Using the periodic medical control apparatus is one aspect of the research activity of members of the crew.

It is important to point out the particularly important role during a prolonged flight of on-board memory units to hold information and digital computers when the medical examination apparatus has many purposes to fulfill. The inevitable communication difficulties over long distances and the complexity and intensity of crew activity make it necessary to retain valuable information on board and to transmit it in condensed form to the Earth. A functional diagram for the medical control apparatus on the ground is shown in Fig. 4.

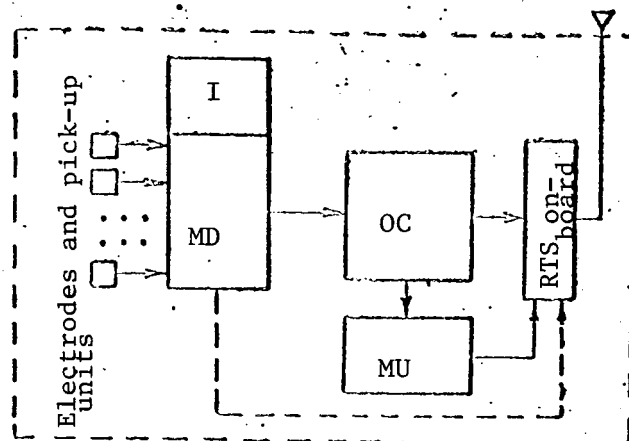


Fig. 3. Functional diagram of a system for periodic medical checks and examination: I -- indicator of channel functioning; MD -- measuring device.

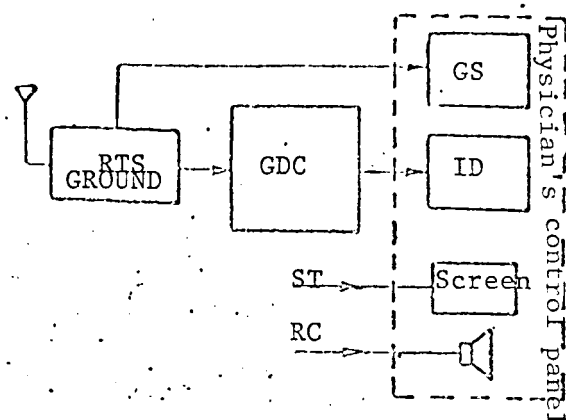


Fig. 4. Ground apparatus of the medical control system: RTS ground -- ground radio-telemetric apparatus; GDC -- ground digital computer; ST -- space television; RC -- radio conversations; GS -- graphic synthesizer; ID -- indicator device.



Inasmuch as future spaceships will change their configuration during flight (docking and separating) and the members of crews will leave their spaceships, the system for maintaining a medical control must be capable of adaptation to the new conditions under which it is used. Therefore, it will be advisable to use radio communication and switching devices for various modes of operation.

In many respects minor biotelemetry (in the cabin and near the space-/7 ship) remains problematical. The theoretical and experimental bases of the principles of its design and many of the basic parameters have not yet been worked out.

Further theoretical and experimental research into the propagation of radio waves in closed areas and development of radio channels which provide for a high degree of reliability in transmitting radiotelemetric information are required.

The experiment conducted by the members of the crew of the "Voskhod-2" should be regarded as the first step in solving the problem of biotelemetric control of the condition of a cosmonaut who has exited from his spaceship in outer space. A simple signalling device which transmitted indicators of pulse and respiration rate to the spaceship commander's control panel permitted him to observe the condition of the cosmonaut who was performing the unique experiment.

Miniaturization and microminiaturization of the apparatus used in biotelemetry constitute a problem which has not yet been completely solved. The methods which are used often prove to be compromises among the factors of optimum dimensions and volume, and reliability and precision of measurements. Moreover, this physiological apparatus must be in keeping with the requirements of the way in which the spaceship is instrumented.

The first step in microminiaturization was the method of micromodular design. For example, the circuit of the bioamplifier developed as the /8 first step in microminiaturization was employed in the space flight of the "Voskhod" as the principal unit of the on-board research instrument used by B. B. Yegorov, the physician-cosmonaut. The amplifier was divided into three types of modules and a certain number of detached parts (capacitors and adjustable components). The selection of parameters of the detached parts made it possible to change the transmission band of the entire amplifying device and its amplification factor within wide limits. Moreover, the modules themselves can be used to construct amplifiers having other functions to perform.

The experience which has been acquired in miniaturizing has indicated that a significant advantage in dimensions through the use of the micromodular design can be gained only in circuits having a sufficiently great number of parts and identical functional units. Film and solid-state circuits are more promising.

The general principle observed in the approach to using methodological and technical innovations in physiological apparatus is that the main criterion of selection must be not only indicators of volume, weight, and power consumption but also criteria of functional reliability and operational safety. The discomfort resulting from the fact itself that pick-up units and electrodes are used on the body of a cosmonaut might cause harm under conditions of intense activity or during sleep. Therefore, the task of specialists who develop the equipment to be used on a man's body is to provide for operational safety.

Pick-up units and electrodes must provide for the recording of information which is of high quality and dependable over an extended period of time. At the present time use is made mainly of electrodes which are held in place with straps and belts and also electrodes which are glued to the skin. These methods have their merits and shortcomings and stand in need of improvement in design as well as replacement by new types. In this regard it is very important that pick-up units and electrodes together with the devices which serve to hold them in place be coordinated in design with the outer and under clothing worn by cosmonauts.

A physiological measuring complex cannot be considered a complete system without inputting information into the on-board digital computer. Using a digital computer is the best solution to processing information most completely, especially that obtained from the operational medical control. The variational limits in the controlled parameters may be given depending on the stages of flight. If all parameters are within the stated limits the digital computer issues the code: "normal". If one or several of the set parameters are being exceeded the digital computer shows the absolute values of these parameters.

Diagnostic problems and defining the condition of cosmonauts will be done from the values of the parameters which are checked when symptoms occur. While in the first, simplest variation in solving a problem of operational /9 medical control the coefficient of information compression (ratio of volume of initial information to volume of processed information) may reach  $10^2$  in solving a diagnostic problem this coefficient may reach  $10^3$ . It is altogether understandable that the output of the digital computer must be connected to a control panel to make mutual control among cosmonauts possible.

However, it is most advisable to use a digital computer for processing the parameters of medical investigation for special programs as well as for periodic examinations for the purpose of predicting the condition of cosmonauts for a required period of time. The possibility of solving problems involving clinical diagnosis cannot be precluded inasmuch as during flight no one has a guarantee against serious illness.

Medical investigation with the use of a digital computer can be carried out according to a preset plan or at the most convenient time. The values of the parameters obtained as a result of processing information through the memory unit and the digital computer will be transmitted to the Earth during regular transmissions. Existing algorithms for processing biomedical

information make possible a coefficient of information compression reaching  $10^3$ .

In conclusion, it should be pointed out that there are many unsolved problems in using the principles of metrology in solving problems in the collection, transmission, and processing of information. In this article we have named only a few of these problems, the solutions to which will produce a significant effect to speed up the progress of cosmonautics and to increase the safety of prolonged space flight by man.

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